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Individual Differences in Developmental Trajectories of Affective Attention and Relations With Competence and Social Reticence With Peers

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This study examined individual differences in affective attention trajectories in infancy and relations with competence and social reticence at 24 months. Data collection spanned 2017 to 2021. Infants ($N = 297$, 53% White, 49% reported as assigned male at birth) recruited in South Central and Central Pennsylvania and Northern New Jersey provided eye-tracking data at five assessments. Caregivers self-reported anxiety symptoms, infant temperamental negative affect, and infant competence at the final assessment. A subgroup of infants participated in a peer social dyad at the final assessment. Using group-based trajectory modeling, we found three groups of infants with different affective attention trajectories: affective attention increasers ($n = 73$), affective attention shifters ($n = 156$), and affective attention decreasers ($n = 50$). Affective attention increasers exhibited low intercepts with steep attention increases, particularly to angry facial configurations. Affective attention shifters exhibited middle intercepts with attention decreases to facial configurations but an attention increase to angry facial configurations. Affective attention decreasers exhibited high intercepts with steep attention decreases. Infants in the affective attention increasers group exhibited more competence when accounting for caregiver anxiety symptoms and infant temperamental negative affect. Group membership was not related to social reticence during the peer social dyad. Infants higher in temperamental negative affect exhibited more social reticence, particularly as the social dyad continued. Our results provide evidence for individual differences in developmental trajectories of affective attention and relations with toddler social behavior. Our results are primarily generalizable to rural and urban populations in the Midatlantic United States.

Keywords: affective attention, longitudinal, person centered, temperament, social reticence

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Affect-biased attention, an automatic process that prioritizes emotionally or motivationally salient stimuli (Todd et al., 2012), is believed to relate to socioemotional outcomes. For example, research suggests that attention to angry facial configurations relates to anxiety in children and adults (Bar-Haim et al., 2007; Clauss et al., 2022). However, these studies often consider affective attention as a static process, whereas recent evidence suggests affective attention, particularly during infancy, develops over the first several years of life (Bierstedt et al., 2022; Peltola et al., 2018; Reider et al., 2022; Vallorani et al., 2023). In fact, recent theories on the development

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The data and data analytic code necessary to reproduce the analyses presented here are publicly accessible on Databrary (LoBue et al., 2021). The analyses presented here were not preregistered.

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of affect-biased attention (Field & Lester, 2010; Morales et al., 2016) suggest that it emerges through a complex coordination of internal and external individual difference factors.

Field and Lester (2010) proposed three potential models for the development of affect-biased attention: the integral bias model, the moderation model, and the acquisition model. The integral bias model suggests that everyone is born with some level of affect-biased attention and that this level remains generally stable across the lifespan. The moderation model suggests that everyone is born with affect-biased attention and that, over time, individual differences shape who retains these biases. The acquisition model suggests that no one is born with affect-biased attention and that individual differences shape who acquires attention biases over time.

To date, research does not support the integral bias model. For example, multiple studies indicate that attention to fearful facial configurations, an indirect signal of threat, emerges around 7 months (Peltola et al., 2008, 2009, 2013) and may dissipate around 24 months (Peltola et al., 2018). Conversely, recent work indicates that attention to angry facial configurations, a direct signal of threat, emerges during the second year of life (Leppänen et al., 2018; Reider et al., 2022). Such results support either the moderation or acquisition models. However, previous work takes a variable-centered approach to assess overall trends in affective attention, whereas the moderation and acquisition models anticipate individual differences in affective attention. A person-centered approach creates the opportunity to investigate potential divergence in the development of affective attention. Modeling individual differences in affective attention is important as these differences might underlie important socioemotional outcomes including social reticence and anxiety risk.

In contrast to variable-centered approaches that assess relations among constructs, person-centered approaches examine how constructs cluster within individuals to identify groups of people with similar behavioral profiles (Laursen & Hoff, 2006). For example, Vallorani et al. (2021) found that when focusing on infant engagement with emotional facial configurations (variable-centered approach), infants of mothers with more anxiety symptoms exhibited less affect-biased attention to both angry and happy facial configurations. However, when focusing on finding groups of infants with distinct patterns of both engagement and disengagement (person-centered approach), infants high in infant temperamental negative affect who also had mothers with more anxiety symptoms were more likely to exhibit affect-biased attention. These cross-sectional analyses demonstrated that we might reach different conclusions about the development of affective attention depending on the type of statistical approach taken.

Our previous work with the current sample used growth curve modeling (a variable-centered approach) to measure the engagement component of affective attention longitudinally (Reider et al., 2022). We found that overall, infants were faster at detecting and spent more time looking at angry facial configurations compared to neutral facial configurations as they got older. However, the addition of group-based trajectory modeling enables us to assess if there are subgroups of infants who show *different* patterns of affective attention over time when compared to the larger group. Importantly, rather than assessing patterns across *tasks*, as in Vallorani et al. (2021), a group-based trajectory model assesses patterns across *time*. This model can identify potential groups of infants who exhibit similar trajectories of affective attention development that diverge from overall trajectories previously observed (Leppänen et al., 2018; Reider et al., 2022). Further, it is possible to assess if there are group differences in trajectories based on interactions between time and emotional facial configurations. That is, a group could show particular attention for angry or happy facial configurations. Observed individual differences in affective attention trajectories could then relate to individual differences in social behavior.

Indeed, theories suggest that social attention is important for the facilitation of social interactions (Capozzi & Ristic, 2018, 2020). Previous work demonstrates that children who exhibit higher fearful temperament during infancy and greater affect-biased attention to angry facial configurations during childhood are more socially withdrawn (Pérez-Edgar et al., 2011). Recent mobile eye-tracking work complicates this previous finding with some evidence indicating that young children higher in fearful temperament spend more time looking at threatening stimuli (Gunther et al., 2021) but that this does not necessarily translate to social withdrawal (Fu et al., 2019). In the peer context, no relation between social attention and fearful temperament was observed among children ages 5 to 7 years (Vallorani et al., 2022). Thus, it is unclear if early patterns of affective attention relate to infant social behavior. Examining the role of affective attention above and beyond additional individual differences, such as infant temperamental negative affect and caregiver anxiety symptoms, could reveal how these various factors contribute to early social behavior.

Infant temperamental reactivity can be measured as early as 4 months of age. Negative reactivity—the combination of high negative affect and high motor activity—is a precursor to fearful temperament and behavioral inhibition (Fox et al., 2015), both of which are known predictors of social anxiety symptoms (Fox & Pine, 2012) and discomfort in social situations (Degnan et al., 2014) during later childhood. Infant temperamental negative affect is also captured through parental report, as with the Infant Behavior Questionnaire and Toddler Behavior Assessment Questionnaire (TBAQ; Gartstein & Rothbart, 2003; Goldsmith, 1996). Here, negative affect is characterized by elevated fear, anger, and sadness, often as a single construct, particularly for infants. Elevated levels of fearfulness at 24 months, as measured by the TBAQ, are associated with increased social reticence at 36 months independent of interaction partner social reticence (Walker et al., 2015). In preschool-aged children, observed negative affect is related to less peer acceptance (Shin et al., 2011). Additionally, at 18 months, temperamental fearfulness is associated with fewer comforting behaviors, an aspect of social competence, when an experimenter exhibits signs of sadness (Schuhmacher et al., 2017).

Caregiver anxiety symptoms may also impact early socioemotional development and behavior like through genetic transmission (Hettema et al., 2001) but perhaps even more influentially through environmental experience (Eley et al., 2015). For example, at 30 months, infants of parents with social anxiety disorder exhibit more fearful behaviors when encountering a novel stimulus (Aktar et al., 2014). Similarly, when parents express anxiety toward novel stimuli, 12-month-old infants higher in behavioral inhibition exhibit more avoidance of the same novel stimulus (Aktar et al., 2013). Additionally, higher maternal anxiety when infants are 2 years old relates to lower infant competence, after accounting for infant effortful control, when infants are 3 years old (Behrendt et al., 2020). Cues from anxious caregivers likely shape how children experience and interpret their world and may guide how infants engage in social interactions. Indeed, mothers with higher levels of anxiety exhibit less sensitivity when interacting with their infants (Ierardi et al., 2019), and mothers who experience more difficulty regulating emotions may have less success in achieving interaction synchrony with their infants (Doba et al., 2022). Infants may learn how to engage in social relationships from interactions with caregivers and carry those lessons into interactions with peers.

The present study takes a person-centered approach to examine individual differences in longitudinal patterns of affective attention across the first 2 years of life. The current eye tracking (Bierstedt et al., 2022; Reider et al., 2022; Vallorani et al., 2023; see details in Supplemental Material S1) and infant temperamental negative affect and caregiver anxiety symptoms (Vallorani et al., 2023) data have been modeled previously using variable-centered approaches. In contrast to previous work modeling the data, the current article focuses on individual differences inherent to affective attention trajectories by modeling the data using group-based trajectory modeling. We then assess if those inherent individual differences in affective attention are associated with socioemotional outcomes, including infant competence and real-world social reticence with peers, in the context of infant temperamental negative affect and caregiver anxiety symptoms.

We used the affective overlap task (Peltola et al., 2008) to assess infant affective attention. In the overlap task, a single face is presented in the center of the screen for 1,000 ms. A checkerboard then appears in the left or right visual field, and the face and checkerboard are presented simultaneously for 3,000 ms. We measured dwell to the face (duration of time), by both fixations and saccades within the facial stimulus area of interest (AOI), in the presence of the checkerboard, representing any time spent in this AOI. This metric captures engagement with the face (Morales et al., 2017; Vallorani et al., 2021, 2023) and is sensitive to the known developmental constraints of gaze shifting in young infants (Hunnius & Geuze, 2004). That is, a longer dwell represents greater engagement with the face, where the infant perseverates upon the face even in the presence of the more recently appearing checkerboard stimulus.

We asked two questions. First, we asked whether we could use group-based trajectory modeling to observe individual differences in developmental trajectories of affect-biased attention. Although a general trajectory of infant affect-biased attention has been previously observed (Reider et al., 2022), we anticipated that we would observe distinct groups of infants with different affective attention trajectories. We anticipated that there would be at least two groups of infants who exhibited either increasing or decreasing affective attention over time. We anticipated that differences could emerge across groups based on emotional facial configuration (Reider et al., 2022). However, we did not have explicit hypotheses about how these differences may emerge. We planned to test multiple solutions and to select the best fitting model for further analyses.

Both infant temperamental negative affect (Fu et al., 2020; Pérez-Edgar et al., 2017; Vallorani et al., 2021) and caregiver anxiety symptoms (Kataja et al., 2019; Morales et al., 2017; Vallorani et al., 2023) likely also play a role in the development of affective attention. However, in the present study, we were underpowered to assess contributions of these individual difference factors to developmental trajectories of affective attention. Instead, we model individual differences inherent to our eye-tracking data. A future larger sample could allow for moderating effects of individual differences on affective attention trajectory group membership to be examined.

Second, we examined if affective attention trajectory group membership related to infant competence, as measured by caregiver report, or social reticence, as measured by observed social behavior, when accounting for infant temperamental negative affect and caregiver anxiety symptoms. Based on previous work, we anticipated that both caregiver anxiety symptoms (Aktar et al., 2013) and infant temperamental negative affect (Andersson et al., 1999; Degnan et al., 2014) would be negatively related to infant competence and positively related to social reticence. Evidence about relations between affective attention and real-world social behavior is mixed. Previous research suggests that children higher in fearful temperament who also exhibit biased attention to angry facial configurations are more socially withdrawn with peers (Pérez-Edgar et al., 2011). However, a recent mobile eye-tracking study did not find that social attention was related to fearful temperament during a peer social interaction (Vallorani et al., 2022). Thus, how infant affective attention might relate to social behaviors remains unclear.

Method

Study Overview

The present study is part of a larger study ($N = 357$) examining the development of attention and temperament across the first 2 years of life (Pérez-Edgar et al., 2021). Data were collected between 2017 and 2021. A community sample was selected to ensure a large spectrum of observed behaviors could be assessed to best characterize possible early risk for anxiety. For the current project, infants provided stationary eye-tracking data during laboratory visits at five assessments between the ages of 3.5 and 29 months ($n = 279$; see Supplemental Material S2 for details on choice to assess at these ages). Caregivers reported their own anxiety symptoms ($n = 149$), their infant's temperamental negative affect ($n = 168$), and their infant's competence ($n = 161$) at the fifth assessment. A subsample of 40 infants (20 reported assigned male at birth) also completed a social dyad at the fifth assessment. Infants were paired based on caregiver reported fearfulness and exuberance and caregiver reported sex and infant age. Caregivers provided informed consent for both their own and their infant's participation. Families were compensated for their participation. Procedures were approved by The Pennsylvania State University and Rutgers University Institutional Review Boards. Data are accessible through Databrary (LoBue et al., 2021) for those participants who consented to data sharing.

Participants

The final sample for the current analyses consisted of 297 infants (146 reported as assigned male at birth) and 182 caregivers (see Supplemental Material S3 for information on missing and excluded data; see Supplemental Material S4 for information about caregivers). A priori power analyses indicated that our sample size was sufficient for our planned analyses (Supplemental Material S5) focused on the eye-tracking and questionnaire data. Importantly, our power analyses indicated that while we were powered to assess potential groups within affect-biased attention trajectories, we did not have sufficient power to include moderators (such as infant temperamental negative affect or maternal anxiety symptoms) in the group-based trajectory model. Due to the COVID-19 pandemic, data collection for the social dyad ended early. However, given the novel nature of our question, assessing relations between individual differences in affective attention and real-world social behavior, we also include descriptive and exploratory analyses on these data for future hypothesis generation.

Participants were recruited via mailings sent to caregivers identified using a university-based database of families interested in research as well as community advertisements. Table 1 displays ages at the eye-tracking assessments and demographics for the sample (see Supplemental Table S1 for subsample demographics). To account for the range of ages at the eye-tracking assessments, data were modeled statistically by age rather than by assessment. Infants were approximately 24 months old at the time of the questionnaire assessments ($M = 24.29$, $SD = 1.10$) and the social dyad visit ($M = 25.02$, $SD = 1.07$).

Measures

Overlap Task

Infants completed a version of the affective overlap task (Morales et al., 2017; Peltola et al., 2008) to assess attention to emotion face configurations. Infants are first presented with a face in the center of the screen for 1,000 ms. A checkerboard then appears in either the left or right periphery of the screen, while the face remains present for 3,000 ms. Thus, the overlap task is designed to assess disengagement from initially presented stimuli to novel stimuli.

Eye-tracking data were collected across sites using SMI eye-tracking systems, either the SMI RED or REDm system, both offering comparable specifications/capabilities (SensoMotoric Instruments, Teltow, Germany). Participants were seated in a highchair ~60 cm from a 22-in. Dell monitor for stimulus presentation. If needed, infants could also sit on their caregiver's lap or on the lap of an experimenter. Gaze was calibrated using a 5-point calibration followed by a 4-point validation, using an animated flower on a black screen and infant-friendly music. Gaze data were sampled at 60 Hz and collected by Experiment Center (SensoMotoric Instruments, Teltow, Germany). Infants/toddlers were calibrated below 4° of visual angle from all calibration points.

Infants were presented with up to 30 experimental trials (fewer when the infant could no longer attend to the task). Each trial was initiated when the infant's attention was on a video clip presented centrally on the screen, which was triggered either when the infant fixated for at least 100 ms or when the experimenter determined that the infant was looking at the video clip. If the participant did not attend to the center of the screen, the slide advanced after 10,000 ms. A face sampled from the NimStim face set (10 actors, of which were five males, providing neutral, happy, and angry closed mouth images; Tottenham et al., 2009) was presented in the center of the screen for 1,000 ms. Face stimuli were approximately 12 cm × 8 cm, and the visual angle of each face was 11.42° × 7.63°. Following the presentation of the face, a checkerboard stimulus then appeared in either the left or right periphery of the screen adjacent to the face (20.78° visual angle) for 3,000 ms. The checkerboard was 12 cm × 2.5 cm, 11.42° × 2.39° visual angle. This progression of stimuli was concluded with a 1,000-ms intertrial interval (blank screen). No consecutive trials were identical in terms of face and probe placement.

AOIs were drawn as ellipses enclosing the face and rectangles enclosing the checkerboards. A 2-cm "error margin" was added to

Table 1
Demographic Information

	First assessment		Second assessment		Third assessment		Fourth assessment		Fifth assessment	
Infant age	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age eye-tracking visit completed	5.04	0.84	8.34	0.62	12.34	0.74	18.31	0.70	24.54	1.12

Infant race/ethnicity					
White	Hispanic	Black	Multiracial	Asian	Not reported
157 (53%)	69 (23%)	39 (13%)	21 (7%)	7 (2%)	4 (1%)

Parent education	Grade school	High school	High school degree	College/ technical school	College degree	Graduate school	Graduate degree	Not reported
Mother's education	8 (3%)	14 (5%)	28 (9%)	46 (16%)	63 (21%)	50 (17%)	59 (20%)	29 (10%)
Father's education	10 (3%)	12 (4%)	37 (12%)	49 (16%)	64 (22%)	36 (12%)	50 (17%)	39 (13%)

Family income		
Below recruitment area median income	Above recruitment area median income	Not reported
71 (24%)	178 (60%)	48 (17%)

each AOI, to account for the deviation permitted in the calibration procedure (max 4°). Analyses were based on gaze to these designated AOIs. Fixations, defined as gaze maintained for at least 80 ms within a 100-pixel maximum dispersion, were extracted with BeGaze (SensoMotoric Instruments, Teltow, Germany). Distribution of valid trials by assessment is reported in Supplemental Table S2. We computed dwell to the central face while the checkerboard stimulus (probe) was present (Morales et al., 2017) for all face configurations (angry, happy, and neutral) using in-house R scripts. For base processing, dwell was defined as the duration of fixations as well as saccades within the designated AOI. Dwells were scaled from milliseconds to seconds. Supplemental Figure S1 displays correlations between raw dwells at each assessment.

Reliability across facial configuration types and assessments was good (split-half reliability scores >.70). Fearful facial configurations are common stimuli in the overlap task, particularly in infants (Peltola et al., 2008, 2009). However, we focused on angry facial configurations due to the larger literature surrounding relations between attention to angry facial configurations and anxiety (Bar-Haim et al., 2007; Clauss et al., 2022).

Infant Temperamental Negative Affect

The TBAQ is a 120-item survey designed to assess general patterns of behavior associated with temperament in young children from 2 to 3 years old (Goldsmith, 1996). The current analysis used data collected at the fifth assessment. Parents rated how often their toddler displayed a specific behavior in the past month using a 7-point Likert scale (*never* to *always*). Each item loads onto one of 11 subscales. Items from each subscale are averaged to obtain scale scores. Goldsmith (1996) reported high levels of convergence with various subscales of the Infant Behavior Questionnaire. For the current analyses, we created a Negativity composite from the TBAQ, composed of the Anger, Sadness, Social Fear, and Object Fear subscales (α = .88).

Caregiver Anxiety Symptoms

The Beck Anxiety Inventory (BAI) is a 21-item self-report questionnaire for evaluating the severity of anxiety in healthy and psychiatric populations (Beck et al., 1988). The current analysis used data collected at the fifth assessment. The BAI was specifically designed to distinguish cognitive and somatic symptoms of anxiety from symptoms of depression. Caregivers rated individual symptoms of anxiety (e.g., fear of losing control) in the past month using a 4-point Likert scale (*not at all* to *severely*). The BAI is scored by adding the highest ratings for all 21 items for a score range from 0 to 63. Higher scores indicate greater symptom severity. Internal reliability was good (α = .89).

Infant Competence

The Infant–Toddler Social and Emotional Assessment is a 200-item survey designed to assess multiple dimensions of social–emotional problems and competencies in 1- to 3-year-old children (Carter et al., 2003). The current analysis used data collected at the fifth assessment. Caregivers described their child on a set of behaviors or attributes for their child (e.g., sleeps through the night; is stubborn) in the past month on a 3-point scale (0 = *Not true/rarely*, 1 = *somewhat true/sometimes*, 2 = *very true/often*). A "No opportunity" code allowed parents to indicate that they have not had the opportunity to observe certain behaviors (e.g., peer interactions). The Infant–Toddler Social and Emotional Assessment includes four subscales: Externalizing, Internalizing, Dysregulation, and Competence. For the current analysis, we focused on the Competence subscale, which includes questions on Attention, Mastery, Motivation, Imitation/Play, Empathy, and Prosocial Peer Relations. Items were averaged to obtain scale scores. Higher scores indicate greater competence. Internal reliability was good (α = .73).

Social Dyad Free Play

The social dyad was completed at the fifth assessment as a measure of infant social reticence during a naturalistic social interaction (Degnan et al., 2014; Garcia-Coll et al., 1984). Dyads were paired based on sex assigned at birth. When possible, we also ensured that infants were not both at the extreme of temperamental fearfulness or exuberance (see Supplemental Material S6). At the beginning of the assessment, families were brought to separate rooms and completed informed consent procedures. Researchers then explained to caregivers that they would be going into another room where their infant would meet another infant and engage in a few tasks. Caregivers were asked that, during this time, they remain as neutral as possible. Additionally, they were provided the paperwork to complete during this time to discourage engagement with their infants. Caregivers and infants were then brought to a new location for the free play. The free-play task began as soon as the infants entered the shared space. The space was set up with a variety of toys available in the center with caregivers seated to the side of the room. The researcher also stood to the side of the space. Infants were allowed 5 min to play freely. The 5-min free-play task was broken into fifteen 20-s epochs.

For every infant, researchers coded each epoch for nine behaviors all on 5-point scales. Codes included activity level (1 = *low levels of movement* to 5 = *high levels of movement*), social interest (1 = *no interaction with dyad partner* to 5 = *full engagement with dyad partner*), wariness (1 = *no hesitation* to 5 = *high levels*), unoccupied (1 = *fully engaged with toys* to 5 = *fully disengaged from toys*), negative affect (1 = *no facial or vocal signals of negative affect* to 5 = *constant facial or vocal signals of negative affect*), positive affect (1 = *no facial or vocal signals of positive affect* to 5 = *constant facial or vocal signals of positive affect*), interaction with researcher (1 = *no direct interaction with the research* to 5 = *constant interaction with the researcher*), interaction with caregiver (1 = *no direct interaction with the caregiver* to 5 = *constant interaction with the caregiver*), and caregiver-initiated interactions (1 = *caregiver does not engage infant* to 5 = *caregiver constantly engages infant*). Each infant was coded separately on a 5-point scale. Five dyads (25%) were double coded. Internal reliability was good (κs for metrics with variability ≥.73; percent agreements with 0 tolerance 100% for metrics with low variability).

A multilevel principal component analysis conducted using the mixOmics package (Rohart et al., 2017) in R indicated social interest, wariness, unoccupied, negative and positive affect, and interaction with caregiver loaded as a single component (Supplemental Table S3). Thus, we created composites (for each epoch and for the entire assessment) of those variables with social interest and positive affect reverse coded to create a single measure of social reticence in line with previous work (Degnan et al., 2014).

Data Analysis

The present study sought to answer two questions. First, we asked if we could identify individual differences in social attention trajectories across the first 2 years of life. Second, we asked how affective attention trajectory group membership, in the context of caregiver anxiety symptoms and infant temperamental negative affect, related to infant competence and social reticence. All analyses were conducted in R 4.3.1 (R Core Team, 2020). Code is accessible through Databrary (LoBue et al., 2021).

To answer Question 1, we employed group-based trajectory modeling. Per our power analysis simulations (see Supplemental Material S5), we were powered to assess linear trajectories. First, we used traditional linear growth modeling using lme4 (Bates et al., 2015) to assess attention trajectories prior to considering the potential for individual differences. Models were fit using REML, which handles missingness in the dependent variable (eye-tracking data). Age in months was divided by 10 prior to inclusion in the models for scaling purposes. Age and emotional facial configuration (0 = *neutral*, 1 = *angry*, 2 = *happy*) were included as fixed effects. Models with and without emotional facial configuration included as a random effect were compared. Age was always included as a random effect.

Then, we used the lcmm package (Proust-Lima et al., 2017) to run heterogenous linear mixed models fit using maximum likelihood estimation, which handles missingness in the dependent variable (eye-tracking data). Age in months was divided by 10 prior to inclusion in the models for scaling purposes. Age and emotional facial configuration (0 = *neutral*, 1 = *angry*, 2 = *happy*) were included as fixed effects. Age was always included as a random and a mixture effect, and emotional facial configuration was always included as a mixture effect. We tested two- and three-group solutions as we were not powered to test beyond three groups. We used the Bayesian information criterion, interpretability, and study design to select our final group-based trajectory model. After model selection, we extracted affective attention trajectory group to assess relations with infant competence and group membership probability to assess relations with social reticence. We used group membership probability when assessing relations with social reticence due to the small sample size.

To answer Question 2, we used linear modeling. Linear models were assessed in lavaan (Rosseel, 2012) using maximum likelihood estimation to handle missing data. Infant competence was entered as a continuous outcome. Affective attention trajectory group was entered as a factor predictor. Infant temperamental negative affect and caregiver anxiety symptoms were entered as continuous predictors. We focused on main effects because, although our overall N was relatively large (N = 297), we were assessing differences between groups with smaller within-group Ns. We included infants who had data for at least one of our metrics of interest (infant competence, affective attention trajectory group, infant temperamental negative affect, and caregiver anxiety symptoms). We controlled for data collection site, which was significantly related to missingness (see Supplemental Material S3 and Supplemental Figure S2) and significantly related to caregiver-reported infant competence and caregiver-reported sex, which was also significantly related to caregiver-reported infant competence.

Given the small sample size for the social reticence data, we focused on data exploration and provide correlations and visualizations. Additionally, we provided exploratory models that account for dyadic interdependence. Our N was not large enough to consider dyad as a random intercept. However, we modeled the data such that self and dyad partner characteristics both had the potential to contribute to observed social reticence. Again, we controlled for data collection site and caregiver-reported sex and included infants who had data for at least one of our metrics of interest (infant social reticence, affective attention group probability, infant temperamental negative affect, and caregiver anxiety symptoms). We provided these exploratory results for future study design and hypothesis generation.

Results

Analysis 1: Group-Based Trajectory Modeling

Linear Growth Models

Supplemental Table S4 displays the best fitting linear growth model, which includes age but not emotional facial configuration, as a random effect (see the data analytic code accessible at https://nyu.databrary.org/volume/1288 for comparison model). Supplemental Figure S3 displays the raw trajectories. We used this model to inform model setup for the group-based trajectory models.

Group-Based Trajectory Models

Table 2 and Figure 1 display the best fitting linear group-based trajectory models (see the data analytic code accessible at https://nyu.databrary.org/volume/1288 for comparison models). Here, we focus on the results of the three-group solution as we selected this as our final model. We selected this solution because (a) it allowed for the interpretation of the contribution of Age × Emotional facial configuration to group membership, and (b) all three groups were of a reasonable size while maintaining a comparable Bayesian information criterion value to the two-group solution. Group 1 (n = 73), which we named *affective attention increasers*, exhibited low intercepts ($b = 0.61$, $p < .001$) with steep attention increases with age ($b = 0.50$, $p < .001$), particularly to angry facial configurations ($b = 0.21$, $p = .010$). Group 2 (n = 156), which we named *affective attention shifters*, exhibited middle intercepts ($b = 1.62$, $p < .001$) with attention decreases with age ($b = -0.17$, $p = .002$) but an attention increase with age to angry facial configurations ($b = 0.14$, $p = .012$). Group 3 (n = 50), which we named *affective attention decreasers*, exhibited high intercepts ($b = 2.55$, $p < .001$) with steep attention decreases with age ($b = -0.62$, $p < .001$) and no specificity for emotional facial configurations.

From the three-group solution, we extracted group membership and set the comparison group as the affective attention shifters, as this group represented the largest number of infants and kept with previous work identifying specificity for increased attention to angry facial configurations in the second year (Leppänen et al., 2018; Reider et al., 2022). We also extracted the probability of being in the affective attention increasers group for our analyses with social reticence, given previous work suggesting heightened attention to angry facial configurations may relate to social withdrawal (Pérez-Edgar et al., 2011). Thus, higher probabilities represent greater likelihood of being in the group exhibiting low intercepts and increasing attention to all facial configurations, but particularly angry facial configurations, over time.

Table 2
Group-Based Trajectory Models Comparison of Two-Group and Three-Group Solution Models

Two-group solution (Group 1, *N* = 128; Group 2, *N* = 151)				
Parameter	Estimate	*SE*	Wald	*p*
Fixed effect in the group membership model				
Intercept Group 1	−0.17	0.23	−0.73	.463
Fixed effect in the longitudinal model				
Intercept Group 1	0.89	0.09	10.02	.000
Intercept Group 2	2.00	0.08	24.94	.000
Age Group 1	0.35	0.07	5.02	.000
Age Group 2	−0.39	0.05	−7.11	.000
Angry Group 1	−0.25	0.08	−2.96	.003
Angry Group 2	−0.05	0.08	−0.65	.514
Happy Group 1	−0.12	0.08	−1.38	.169
Happy Group 2	0.06	0.08	0.76	.445
Age × Angry Group 1	0.20	0.06	3.35	.001
Age × Angry Group 2	0.07	0.05	1.34	.179
Age × Happy Group 1	0.08	0.06	1.36	.174
Age × Happy Group 2	−0.03	0.05	−0.59	.555
Random effect				
Residual *SE*	0.41	0.01		

Goodness-of-fit statistics		
Log likelihood	AIC	BIC
−1278.25	2588.50	2646.60

Three-group solution (Group 1, *N* = 73; Group 2, *N* = 156; Group 3, *N* = 50)				
Parameter	Estimate	*SE*	Wald	*p*
Fixed effect in the class membership model				
Intercept Group 1	0.42	0.31	1.36	.174
Intercept Group 2	1.02	0.24	4.26	.000
Fixed effect in the longitudinal model				
Intercept Group 1	0.61	0.12	4.99	.000
Intercept Group 2	1.62	0.08	20.54	.000
Intercept Group 3	2.55	0.12	21.67	.000
Age Group 1	0.50	0.11	4.62	.000
Age Group 2	−0.17	0.06	−3.02	.002
Age Group 3	−0.62	0.10	−6.03	.000
Angry Group 1	−0.24	0.11	−2.20	.028
Angry Group 2	−0.17	0.08	−2.19	.029
Angry Group 3	0.10	0.13	0.74	.462
Happy Group 1	−0.09	0.11	−0.78	.433
Happy Group 2	−0.04	0.08	−0.56	.578
Happy Group 3	0.16	0.13	1.19	.236
Age × Angry Group 1	0.21	0.08	2.59	.010
Age × Angry Group 2	0.14	0.05	2.51	.012
Age × Angry Group 3	0.01	0.10	0.15	.882
Age × Happy Group 1	0.05	0.08	0.56	.572
Age × Happy Group 2	0.05	0.06	0.84	.403
Age × Happy Group 3	−0.11	0.10	−1.10	.272
Random effect				
Residual *SE*	0.41	0.01		

Goodness-of-fit statistics		
Log likelihood	AIC	BIC
−1259.75	2565.49	2649.01

Note. Heterogenous linear mixed model fitted by maximum likelihood method over 279 subjects (1,750 observations). *SE* = standard error; AIC = Akaike information criterion; BIC = Bayesian information criterion.

Analysis 2A: Contributions of Affective Attention Trajectory Group, Infant Temperamental Negative Affect, and Caregiver Anxiety Symptoms to Infant Competence

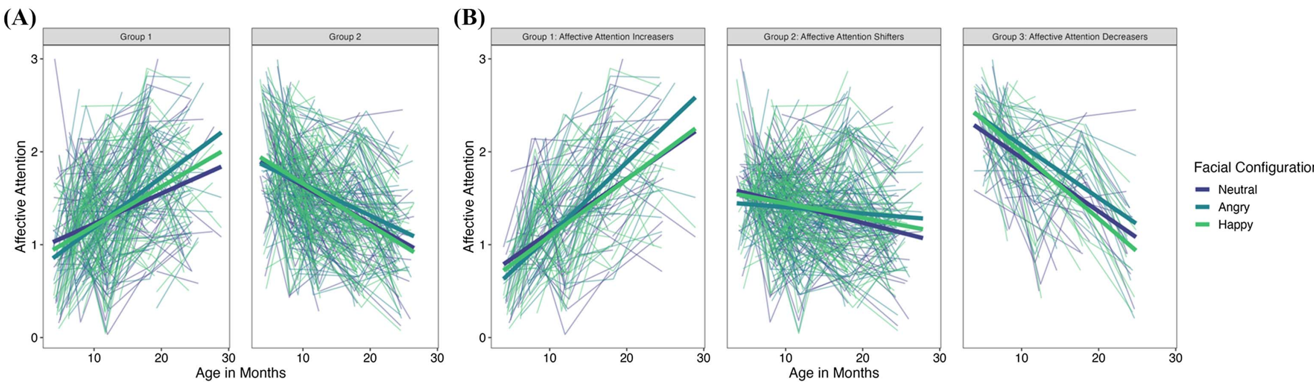
Table 3 displays zero-order correlations and descriptive statistics among variables of interest. Table 4 and Figure 2 display the results of the linear model. We found that infants in the affective attention increasers group showed higher levels of competence at the final assessment than infants in the affective attention shifters group (b = 0.12, p = .040). We also saw that caregivers rated infants assigned female at birth as exhibiting higher levels of competence than infants assigned male at birth (b = 0.15, p = .001). Neither infant temperamental negative affect (b = −0.05, p = .154) nor caregiver anxiety symptoms (b = 0.00, p = .893) were associated with infant competence.

Analysis 2B: Contributions of Affective Attention Trajectory Group Probability, Infant Temperamental Negative Affect, and Caregiver Anxiety Symptoms to Social Reticence

Table 5 displays zero-order correlations and descriptive statistics among the variables of interest. Social reticence in the naturalistic social interaction context was not related to the probability of being in the affective attention increasers group (r = −.07, p = .541) or caregiver anxiety symptoms (r = .06, p = .751). However, we did observe that caregiver-reported infant temperamental negative affect was associated with researcher-observed social reticence during the social interaction (r = 0.41, p = .015). Additionally, researcher-observed social reticence at the beginning of the social interaction (within the first minute) was unrelated to caregiver-reported infant temperamental negative affect (r = .20, p = .242). However, continued displays of social reticence *over time* were related to caregiver-reported infant temperamental negative affect (r = .44, p = .008). Figure 3 provides a visual representation of these relations. Further, Supplemental Figure S4 displays infant temperamental negative affect and social reticence across the social interaction for dyad pairs.

We conducted additional exploratory models to account for potential dyadic interdependence in these relations (Supplemental Table S5). We found that even when accounting for partner characteristics, an infant's own temperamental negative affect specifically was related to social reticence (b = 0.76, p = .001). Additionally, the effect was weaker at the beginning of the interaction (b = 0.49, p = .030) but stronger as the interaction continued (b = 0.82, p = .001). Interestingly, partner social reticence had very small estimates. However, partner temperamental negative affect had

Figure 1
Comparison of Two-Group (A) and Three-Group (B) Models



Note. The three-group solution was selected for further analyses. *Affective attention increasers* ($n = 73$) exhibited low intercepts and steep attention increases with age, particularly to angry facial configurations. *Affective attention shifters* ($n = 156$) exhibited intercepts between the other two groups and attention decreases with age but an attention increase with age to angry facial configurations. *Affective attention decreasers* ($n = 50$) exhibited high intercepts with steep attention decreases with age and no specificity for emotional facial configurations. See the online article for the color version of this figure.

estimates, though nonsignificant, comparable to infant temperamental negative affect. This could be valuable to note in terms of future hypothesis generation. Similarly, neither infant nor partner affective attention group probability was significantly related to infant social reticence. However, the estimates were directionally in line with the results of the infant competence analyses. Again, this could be valuable for future hypothesis generation. Overall, given the small sample size, these observations should be taken as an opportunity for hypothesis generation and future study development as explored in the discussion.

Discussion

The current article sought to characterize individual differences in developmental trajectories of affective attention and relations with infant competence and social reticence in the context of infant temperamental negative affect and caregiver anxiety symptoms. Our results indicated that different patterns of infant trajectories of affective attention exist and are associated with infant competence. Infant affective attention group was not associated with social reticence. However, infant temperamental negative affect was associated with infant social behavior. These results highlight the utility of a person-centered approach to investigating affective attention development. Additionally, they suggest the need for further naturalistic methods—such as using mobile eye tracking to assess attention *during* social interactions—to understand the complex interplay between affective attention, caregiver anxiety, temperament, and social behavior.

Our current results provide additional evidence against the integral bias model of affect-biased attention development and support either the moderation or acquisition models (Field & Lester, 2010) or a hybrid model (Morales et al., 2016). In contrast to the integral bias model, which anticipates that affect-biased attention is stable over time, we show change in affective attention over time in keeping with a growing body of work showing that affective attention changes with development (Peltola et al., 2018; Reider et al., 2022; Vallorani et al., 2023). Our present study design is unable to definitively differentiate between models of affect-biased attention. To differentiate between these models, infants would need to be assessed from birth, which might pose challenges due to constraints related to infant eye tracking (Hunnius & Geuze, 2004). Additionally, it would be important to assess potential moderators, such as temperament or caregiver anxiety symptoms, within the group-based trajectory model. This would require a larger sample.

Our previous research using growth curve modeling (a variable-centered approach) suggests that infants increase attention to angry

Table 3
Zero-Order Correlations and Descriptive Statistics

Variable	1	2	3	4	5	6	7	*N*	*M*	*SD*
1. Site	—	.07	.25**	.05	−.07	.13	−.32**	297		
2. Sex		—	.06	.02	.08	.23**	.16*	297		
3. Age at questionnaires			—	−.13	.01	.05	−.07	182	24.29	1.10
4. Affective attention group				—	−.10	.01	.07	279		
5. Caregiver anxiety symptoms					—	.06	.01	149	5.48	6.79
6. Infant temperamental negative affect						—	−.08	168	3.33	0.70
7. Infant competence							—	161	1.32	0.31

Note. Affective attention group: Affective attention shifters = 0; affective attention increasers = 1; affective attention decreasers = 2.
* $p < .05$. ** $p < .01$.

Table 4

Linear Model Assessing Contributions of Affective Attention Trajectory Group Membership, Infant Temperamental Negative Affect, and Caregiver Anxiety Symptoms to Infant Competence at 24 Months

Parameter	Estimate	*SE*	*z*	*p*
Intercept	1.45	0.11	13.20	.000
Site 2	−0.06	0.06	−1.02	.307
Site 3	−0.28	0.06	−5.12	.000
Female at birth	0.15	0.05	3.20	.001
Affective attention increasers	0.12	0.06	2.05	.040
Affective attention decreasers	−0.02	0.07	−0.28	.781
Infant temperamental negative affect	−0.05	0.03	−1.43	.154
Caregiver anxiety symptoms	0.00	0.00	−0.13	.893

Note. $N = 297$. $R^2 = .23$. Factor variables: Site 1 = 0, Site 2 = 1, Site 3 = 2; male = 1, female = 2; affective attention shifters = 0, affective attention increasers = 1, affective attention decreasers = 2. *SE* = standard error.

facial configurations, but not happy facial configurations, compared to the neutral facial configurations across the first 2 years of life (Reider et al., 2022). Using group-based trajectory modeling (a person-centered approach), we found three groups of infants who exhibited different affective attention trajectories over the first 2 years of life. The affective attention increasers group exhibited low intercepts and steep increases in attention to emotional facial configurations, particularly angry facial configurations, over time. The affective attention shifters group exhibited intercepts that fell between the other two groups and moderate decreasing attention to facial configurations but moderate increasing attention to angry facial configurations specifically, which is somewhat consistent with previous work (Reider et al., 2022). The affective attention decreasers group exhibited high intercepts and steep decreases in attention to emotional facial configurations with no specificity for emotional context.

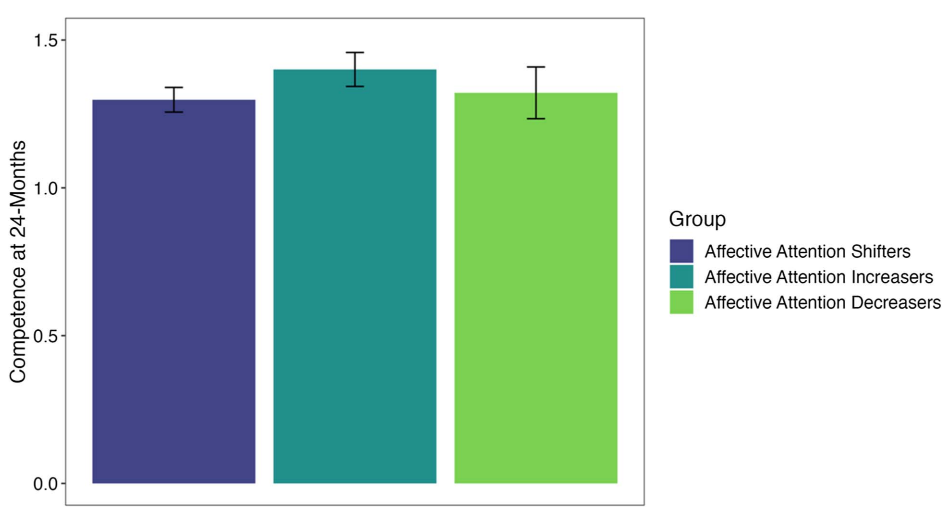
After obtaining these groups, we examined if group membership related to infant competence. We set the affective attention shifters group as our comparison group because it included the most infants. Previous work suggested that infants biased toward angry facial configurations exhibit more social withdrawal (Pérez-Edgar et al., 2011). However, our results suggested that infants in the affective attention increasers group exhibited more competence than infants in the affective attention shifters group. Data suggest that increases in attention to angry facial configurations are expected in the second year of life (Leppänen et al., 2018; Reider et al., 2022). Thus, it could be that those infants who are showing steep increases to affective information in general, even if there is a greater increase in attention to angry facial configurations, are absorbing more social information and are more actively engaged in social learning (Vallorani et al., 2022). We did not find that infant temperamental negative affect or caregiver anxiety symptoms related to infant competence.

An important goal of the current article was to examine relations between individual differences in affective attention trajectories, caregiver anxiety symptoms, and infant temperamental negative affect with real-world social reticence. Unfortunately, our social dyad sample was smaller than originally planned due to the COVID-19 pandemic. Thus, we consider these results exploratory and useful for future study design and hypothesis generation. We did not find that caregiver anxiety symptoms were related to infant social reticence. Previous evidence suggests caregiver anxious expressions during a novel experience (Aktar et al., 2013) or social anxiety specifically (Aktar et al., 2014), rather than overall trait levels of anxiety, are related to infant avoidance of novelty. Possibly, trait caregiver anxiety is not a good predictor of infant social behavior.

We did observe that higher infant temperamental negative affect was associated with social reticence, particularly during the later

Figure 2

Relation Between Affective Attention Trajectory Group Membership and Infant Competence at the Final Assessment



Note. Infants in the affective attention increasers group exhibited more competence at 24 months than did infants in the affective attention shifters group. See the online article for the color version of this figure.

Table 5

Zero-Order Correlations and Descriptive Statistics for Dyadic Social Interaction

Variable	1	2	3	4	5	6	7	8	*N*	*M*	*SD*
1. Site	—	.12	.49**	−.13	.26	−.22	−.30	−.20	40		
2. Sex		—	.24	−.33	−.04	.01	.00	.01	40		
3. Affective attention group probability			—	−.33	.11	−.07	−.15	−.05	39	0.23	0.35
4. Caregiver anxiety symptoms				—	.06	−.04	.13	−.08	35	6.31	6.34
5. Infant temperamental negative affect					—	.41*	.20	.44**	35	3.37	0.57
6. Social reticence (total)						—	.87***	.99***	40	2.93	0.85
7. Social reticence (Minute 1)							—	.81***	40	3.00	0.77
8. Social reticence (Minutes 2–5)								—	40	2.92	0.90

Note. Affective attention group probability represents the probability of being in the affective attention increasers group.
* $p < .05$. ** $p < .01$. *** $p < .001$.

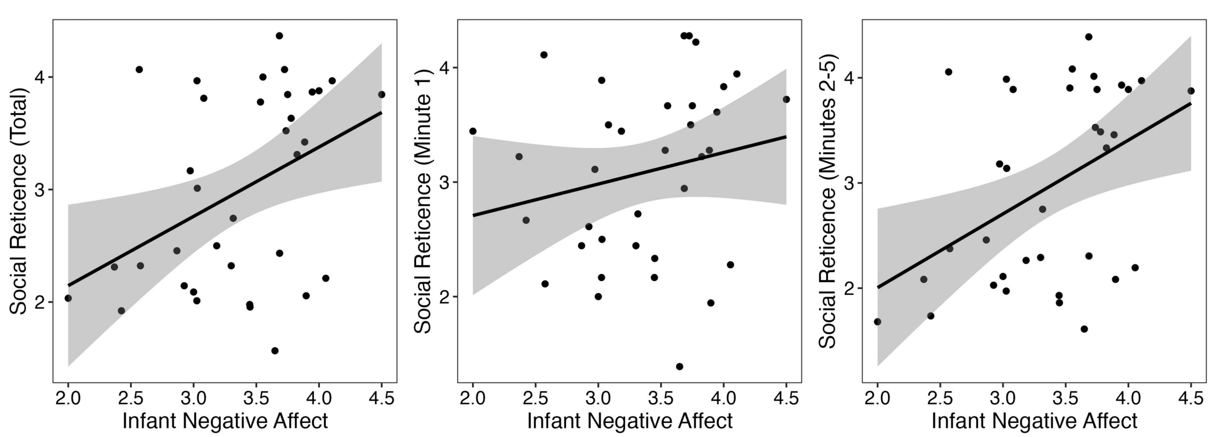
portion of the social dyad, consistent with previous work showing relations between fearful temperament and social discomfort with peers (Degnan et al., 2014). The results suggest that infant temperamental negative affect may be related to difficulty "warming up" to a novel social situation. Importantly, the results were consistent when accounting for dyad partner characteristics. No relation between caregiver anxiety symptoms and infant temperamental negative affect was observed. Although it was not a focus of our research questions, this was surprising given that greater caregiver anxiety is often associated with greater infant temperamental negative affect (Brooker et al., 2015; Vallorani et al., 2023).

Previous evidence examining relations between affect-biased attention, temperament, and social behavior are mixed (Pérez-Edgar et al., 2011; Vallorani et al., 2022). Theories suggest that social attention is essential for navigating social interactions (Capozzi & Ristic, 2018, 2020). However, we also did not observe significant relations between probability of being in the affective attention increasers group and social reticence. Thus, we anticipated that individual differences in infant attention might relate to social reticence. Given the exploratory nature of the analyses and the goal of providing data for future hypothesis generation, we do note that the effects of infant and partner probability of being in the affective attention increasers group, though not significant, were negatively associated with social reticence, echoing the more robust analyses assessing infant competence. Additionally, we note that the effects of partner temperamental negative affect, though not significant, were similar to the effects of infant temperamental negative affect, while the effect of partner social reticence was very small. These exploratory results should not be definitively interpreted. However, they may aid researchers in future study design and hypothesis generation as they leave several questions open for further investigation.

First, it is important for future research to measure social attention during social interactions. Mobile eye tracking can elucidate hidden patterns between social attention and affective expressions. For example, recent research in young children suggests that expressions of positive affect are related to greater attention to peers (Vallorani et al., 2022). Additionally, adolescent daughters are avoidant of emotional facial expressions when engaged in difficult conversations with their mothers (Woody et al., 2021). Capturing attention throughout an infant peer social interaction could help us to understand what might keep infants higher in negative affect

Figure 3

Scatterplots Representing Relations Between Infant Negative Affect and Social Reticence During the Naturalistic Social Interaction



Note. Infant negative affect was significantly related to fearful behaviors across the entire interaction and during the latter portion of the social interaction but not during the first minute of the social interaction.

from warming up to the situation. For example, perhaps infants higher in negative affect spend more time gazing at caregivers than at toys or peers, particularly during the later portion of a social interaction. Further, researchers can leverage group-based trajectory modeling to understand individual differences in social attention trajectories over the course of a social interaction (Gunther et al., 2022). Such modeling might help explain how patterns of social attention relate to social behavior in the moment.

Second, rather than relying on measures of trait anxiety, it may be beneficial to assess caregivers' anxious expressions (Aktar et al., 2013) or caregivers' parenting behaviors (Kalomiris & Kiel, 2016) during social interactions. Infants higher in temperamental negative affect might spend more time looking at caregivers instead of playing. If caregivers are also showing anxious expressions, infants already looking at caregivers may be more exposed to anxious cues. Such cues might suggest an unsafe environment. In the current small sample, our caregivers did not exhibit many overprotective behaviors during the social interaction. However, future research could intentionally recruit caregivers higher in anxiety to examine these potential relations. Further, the social interaction could be designed to observe social interactions between both caregivers and infant peers simultaneously to examine how caregiver attention and behavior throughout might influence infant social behavior.

Our findings should be considered with limitations in mind. First, caregivers reported both their own anxiety symptoms and their infant's temperamental negative affect. It is possible that reporter bias shaped our results. However, given there was no relation between caregiver anxiety and infant temperamental negative affect in either the larger (r = .06) or smaller (r = .06) sample, it does appear that caregivers were able to differentiate between their own and their infant's experiences. Additionally, our measure of social reticence during the peer social interaction was independently coded by researchers and did relate to infant temperamental negative affect (r = .41). Thus, we believe the impact of reporter bias was minimal.

Second, we were unable to assess for potential moderators, such as temperament or caregiver anxiety, within the actual group-based trajectory model. As such, this limits our ability to differentiate between potential models of affect-biased attention development, though we feel confident in our assessment that our model does not support the integral bias model. A larger sample would provide the power necessary to include potential moderators in the model. The lack of moderators in the model may also reduce our ability to observe potential effects with social behavior. However, it is difficult to say in this case if the lack of effect of affective attention group on social reticence was due to not including potential moderators in the group-based trajectory model or due to the small sample size.

Third, we focused on angry facial configurations in our present study design based on previous work linking affect-biased attention to direct threats with anxiety and anxiety risk (Bar-Haim et al., 2007; Clauss et al., 2022). However, many researchers examine attention to fearful facial configurations during infancy (Peltola et al., 2008), and newer work suggests the existence of attention biases to more than just angry facial configurations (Burris et al., 2017; Vallorani et al., 2023). Future work should continue to examine multiple facial configurations to better understand how affect-biased attention relates to anxiety risk.

Finally, there are constraints on generalizability. The present study was conducted in a diverse sample of caregivers and their infants within the Midatlantic United States. Our study sampled from both rural and urban populations. Additional work would need to assess affective attention development across regions of the United States and internationally to make broader statements about the generalizability of the current results.

In conclusion, our findings suggest that individual differences in traits known to associate with socioemotional development may drive the development of different trajectories of affective attention over time. Infants in the affective attention increasers group exhibited more competence, but a similar relation was not significant in the smaller sample assessing real-world social reticence. Infants higher in temperamental negative affect exhibited more social reticence, particularly as the social interaction progressed and even after accounting for dyad partner characteristics. We recommend that future work incorporates mobile eye tracking into social interactions with peers and caregivers to better assess relations between individual differences in affective attention, caregiver anxiety, temperament, and social behavior in the moment.

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